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EXCLUSIVE SPIN-DEPENDENT PION PRODUCTION IN MEDIUM-ENERGY NUCLEON-NUCLEON COLLISIONS

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ABSTRACT

Application of a unitary, relativistic three-body isobar model to the reaction $pp \rightarrow np\,\pi^+$ at 800 MeV gives a good parameter-free representation of the exclusive spin-averaged cross section and asymmetry.

In recent years a surprisingly rich spin-dependence in the nucleon-nucleon interaction at medium energies has been uncovered. One example is the structure found in the spin-dependent total cross section differences, $\Delta\sigma_L$ and $\Delta\sigma_T$. This is sufficiently striking to lead to conjectures of dibaryon resonances, although at least part of the structure seen in this region is due to the strong coupling to the $NN \rightarrow NN\,\pi$ inelastic channel. Thus it is of interest to look at the spin-dependence of single-pion production. This is especially true now because of the appearance of the first extensive exclusive spin-dependent measurements of the important $pp \rightarrow np\,\pi^+$ reaction.[1]

This experiment measures the differential cross section for in-plane geometry with transversely polarized incident protons of 800 MeV kinetic energy. Final state protons and pions are observed in a magnetic spectrometer and time-of-flight arm, respectively. The asymmetries are typically quite large, and this has been interpreted as supporting evidence for dibaryons in the $^1D_2$ and $^3F_3$ partial waves.[2]

This conclusion was based, however, on a Born approximation (BA) calculation for the isobar amplitudes such as $NN \rightarrow N\Delta$. Since an asymmetry involves a relative imaginary part between a spin-nonflip and a spin-flip amplitude, it is not surprising that small asymmetries result without a mechanism for generating phase differences. One way of doing this, in contrast to the ad hoc inclusion of dibaryon amplitudes, is to use fully unitarized isobar amplitudes.

These amplitudes are now available from relativistic, unitary, three-body model calculations with full spin-dependence. The model is described in detail elsewhere.[3] Briefly, we solve the Blankenbecler-Sugar coupled integral equations for the $NN \rightarrow N\Delta$ and $NN \rightarrow NN'$ amplitudes with one-pion-exchange driving terms. The $NN \rightarrow NN\,\pi$ amplitudes are then found in a straightforward way by including factors for the isobar preparation (like Breit-Wigner resonance factors) and the

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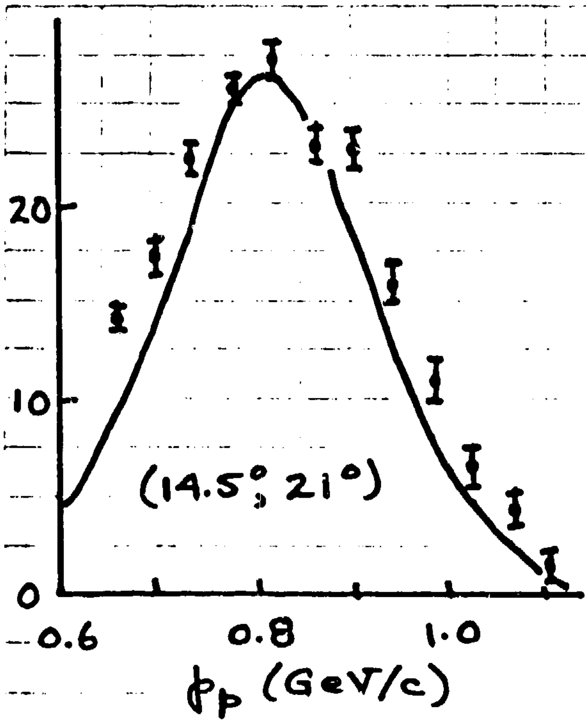

Fig. 1. $d\sigma/dp_p d\Omega_p d\Omega_\pi$ at 800 MeV, in mb(GeV/c)$^{-1}$(sr)$^{-2}$. Data are from Refs. 1 and 2.

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p-wave breakup vertex. For the exclusive kinematic situation discussed here, no integration over unobserved phase space is necessary.

Figure 1 shows results of the model for one angle pair for 800 MeV incident protons for the unpolarized differential cross section. No parameters have been adjusted other than the specified two-body πN input. The agreement here may not be too surprising in view of the model's success with the total spin-averaged NN → NNπ cross section.[4]

Results for the asymmetry, $A_N = [\sigma(\uparrow) - \sigma(\downarrow)]/[\sigma(\uparrow) + \sigma(\downarrow)]$, are shown in Fig. 2. The trend of the data is well represented by the model. In particular, the large asymmetries come out naturally. Again, no parameters have been adjusted. The effects of including short-range forces[5] remain to be seen.

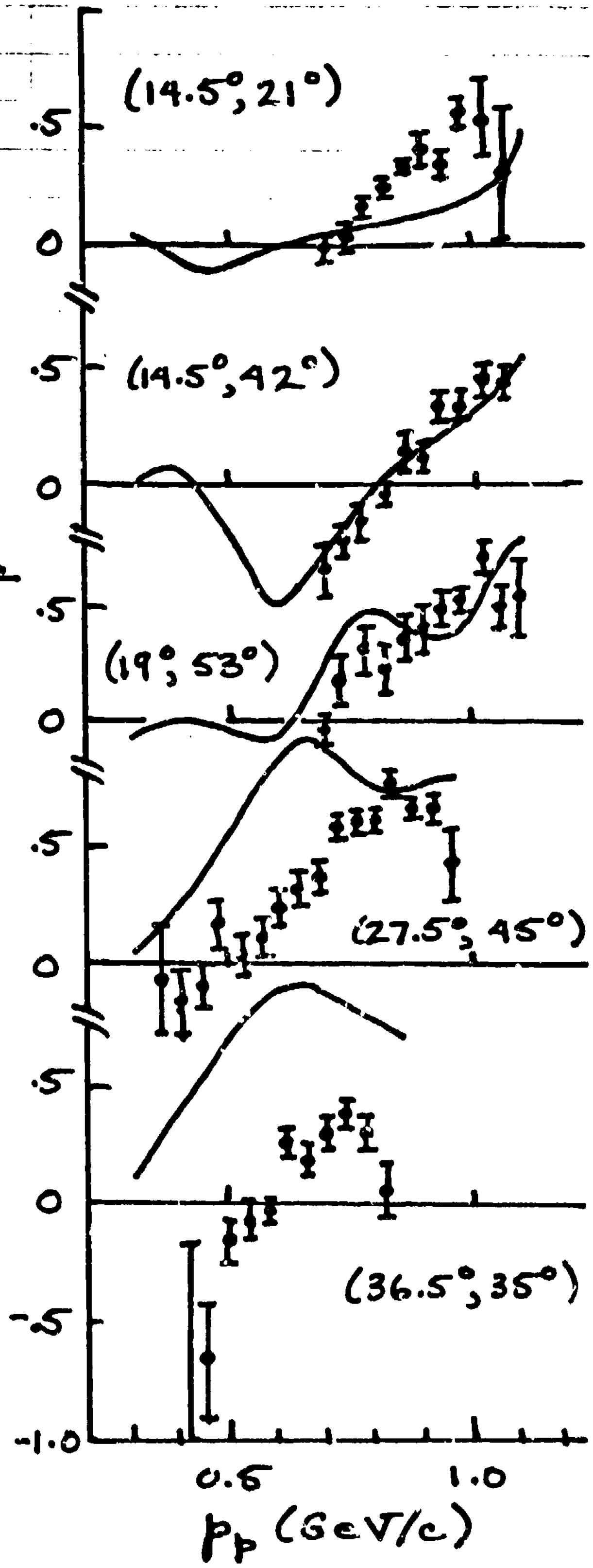

Fig. 2. Asymmetry A_N for $p\uparrow p \rightarrow np\pi^+$ at 800 MeV, for various angle pairs. Data are from Refs. 1 and 2.

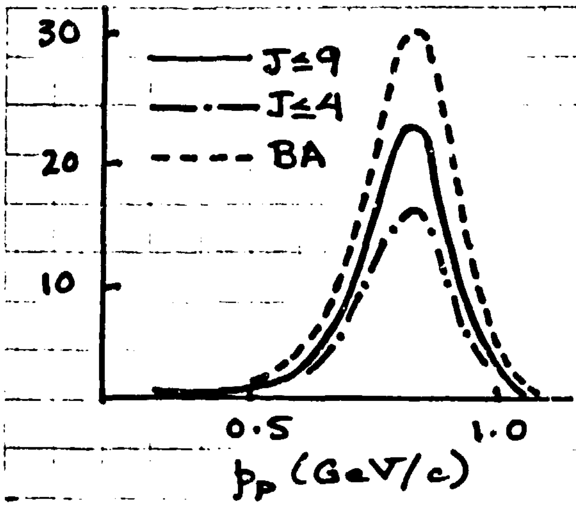

Fig. 3. Model dependence of exclusive, spin-averaged cross section at 800 MeV for (20°,22°).

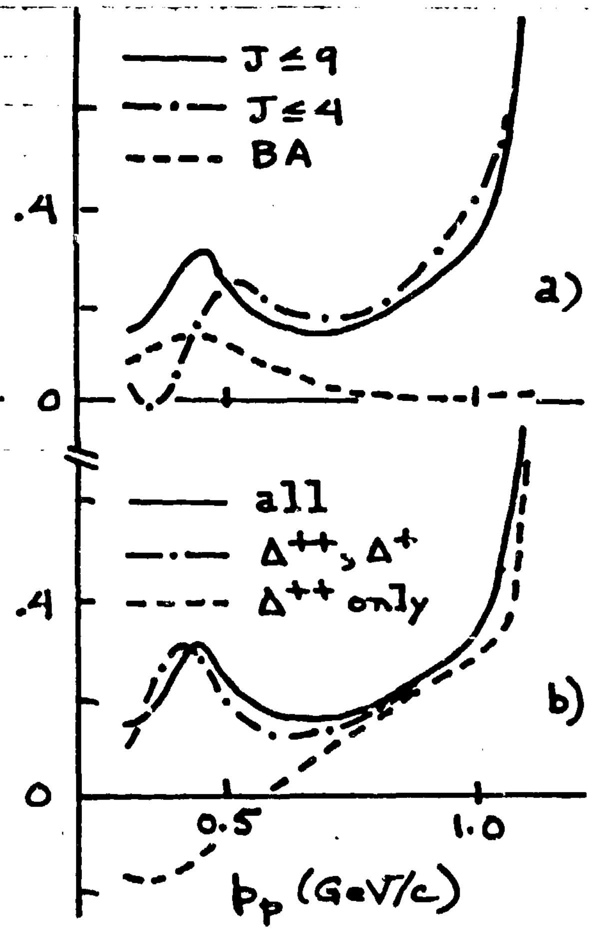

Fig. 4. Model dependence of A_N at 800 MeV for (20°,22°).

The model sensitivity of both the exclusive cross section and asymmetry are illustrated in Figs. 3 and 4. The effect of unitarization of the isobar amplitudes is quite apparent, especially for A_N. It is surprising, moreover, how important the higher partial waves are; the amplitudes with $5 \leq J \leq 9$ increase the peak value of the cross section by about 35%! This is quite different from the usual isobar model assumptions.[6]

To conclude, we have found that the unitarized, relative isobar model of Ref. 3 gives quite reasonable predictions of the asymmetry and exclusive cross sections for $pp \rightarrow np\,\pi^+$ at 800 MeV. The Born approximation does not, especially for the asymmetry, which is quite sensitive to model details. In particular the present results demonstrate that there is no need for introducing explicit dibaryon resonances to explain the surprisingly large A_N.

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